Topic 9 – Chemistry of the atmosphere

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9.1 The composition and evolution of the Earth's atmosphere

9.1.1 The proportions of different gases in the atmosphere

- Nitrogen - 80%
- Oxygen – 20%
- Small proportions of other gases, including carbon dioxide, water vapour & noble gases

There is not much O_2 in the atmosphere of Mars. Suggest why (1)

- Mars has no plants

The percentage of argon in Earth's atmosphere today is same as it was in early atmosphere. Why? (2)

- Argon is a noble gas
- Unreactive coz have full & stable outer shell

9.1.2 The Earth's early atmosphere

1. Intense volcanic activity that released gases that formed the early atmosphere
2. Water vapour that condensed to form the oceans.
3. At the start of this period the Earth's atmosphere may have been like the atmospheres of Mars & Venus today, consisting mainly CO_2 with little or no O_2 gas
4. Volcanoes also produced N_2 which gradually built up in the atmosphere & there may have been small proportions of CH_4 & NH_3
5. When oceans formed, CO_2 dissolves in the water & carbonates were precipitated producing sediments, reducing amount of CO_2 in atmosphere
6. Earth cooled further, reducing no of volcanoes and form crust. Soon continents are formed.
7. Algae & plants produced O_2 that is now in the atmosphere by photosynthesis, which can be represented by the equation: $6CO_2 + 12H_2O \xrightarrow[chlorophyll]{light} C_6H_{12}O_6 + 6O_2\ 6H_2O$

Describe what happened to CO2 in Earth's early atmosphere (3)

- CO_2 is absorbed by plants for photosynthesis
- Dissolves in ocean
- Used to form shells & skeletons of marine organisms
- Locked up as limestone & fossil fuels/coal/crude oil

Describe & explain how composition of Earth's atmosphere was changed by formation of coal. (3)

- Plants absorb CO_2 & releases O_2 by photosynthesis. This causes CO_2 to decrease & O_2 to increase in atm
- CO_2 is also locked up as coal so CO_2 decreases

Explain how CO_2 is released from limestone (1)

- Thermal decomposition of calcium carbonate
- $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Where did the carbon that is locked up in fossil fuels come from? (1)

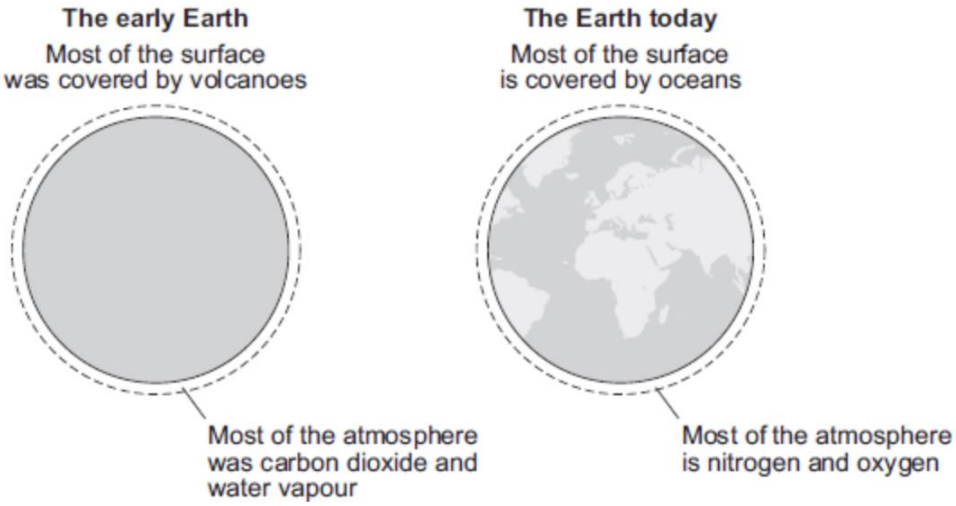
- CO_2 in Earth's early atmosphere

The burning of fossil fuels has caused the percentage of carbon dioxide in the atmosphere to increase to above 0.03%. Explain why (2)

- Increasing in burning fossil fuels
- Coz CO_2 that is locked up as fossil fuels reacts with O_2 & produce CO_2

In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

This Earth and its atmosphere today are not like the early Earth and its atmosphere.



Describe and explain how the surface of the early Earth and its atmosphere have changed to form the surface of the Earth and its atmosphere today. (6)

Main changes

- Oxygen increased because plants / algae developed and used carbon dioxide for photosynthesis / growth producing oxygen; carbon dioxide decreased because of this
- Carbon dioxide decreased because oceans formed and dissolved / absorbed carbon dioxide; carbon dioxide became locked up in sedimentary / carbonate rocks and / or fossil fuels
- Oceans formed because the Earth / water vapour cooled and water vapour in the atmosphere condensed
- Continents formed because the Earth cooled forming a supercontinent / Pangaea which formed the separate continents
- Volcanoes reduced because the Earth cooled forming a crust

Other changes

- Nitrogen has formed because ammonia in the Earth's early atmosphere reacted with oxygen / denitrifying bacteria

Why don't scientists know accurate composition of Earth's early atmosphere? (1)

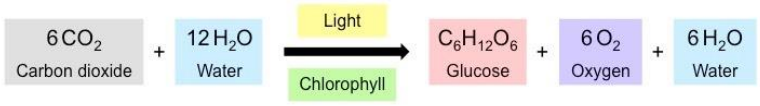
- Too long ago (time scale of 4.6 billion years)

In 1915, Alfred Wegener had an idea that the change shown in the diagram was caused by continental drift. Most scientists could not accept his idea.
Suggest why most scientists in 1915 could not accept Wegener's idea of continental drift (1)

- Wegener had no evidence

9.1.3 How oxygen increased

Algae & plants produced O_2 by photosynthesis



Plants evolved & percentage of O_2 increased → able animals to evolve

9.1.4 How carbon dioxide decreased

For the last 200 million years the amount of carbon dioxide in the atmosphere has remained almost the same.

Describe the natural processes which remove carbon dioxide from the atmosphere.

To gain full marks in this question you should write your ideas in good English. Put them into a sensible order and use the correct scientific words. (4)

- Plants take in (CO_2)
- Converted to glucose / starch / carbohydrates
- CO_2 locked up in fossil fuels
- CO_2 reacts with / dissolves (sea)water
- Producing hydrogencarbonates / carbonates
- Marine animals use carbonates to make shells
- Forms sedimentary rocks / limestone / chalk

Scientists study the atmosphere on planets and moons in the Solar System to understand how the Earth's atmosphere has changed.

(a) Millions of years ago the Earth's atmosphere was probably just like that of Mars today.

The table shows data about the atmospheres of Mars and Earth as they are now.

Mars		Earth	
nitrogen	3%	nitrogen	78%
oxygen	trace	oxygen	21%
water	trace	water	trace
carbon dioxide	95%	carbon dioxide	trace
Average surface temperature –23 °C		Average surface temperature 15 °C	

Suggest what has caused the main gases in the Earth's atmosphere of millions of years ago to change to the present-day atmosphere.

Carbon dioxide has <u>decreased</u> due to:

- Plants / microorganisms / bacteria / vegetation / trees
- Photosynthesis
- 'Locked up' in (sedimentary) rocks / carbonates / fossil <u>fuels</u>
- Dissolved in oceans

Oxygen has <u>increased</u> due to:

- Plants / bacteria / microorganisms / vegetation / trees
- Photosynthesis

Nitrogen <u>increased</u> due to:

- Ammonia reacted with oxygen

- Bacteria / micro organisms

9.2 Carbon dioxide and methane as greenhouse gases

9.2.1 Greenhouse gases

- Maintain temp on Earth high enough to support life
- Greenhouse gases – $H_2O_{(g)}$, CO_2, CH_4

Describe greenhouse effect in terms of the interaction of short and long wavelength radiation with matter

- Energy from sun passes through atmosphere as short wavelength radiation eg UV & visible light coz short wavelength radiation doesn't interact strongly with gas molecules in atmosphere
- Some energy absorbed by earth & heats up the earth's surface
- Some reflects back towards space as long wavelength radiation. They are then absorbed by greenhouse gases in atmosphere
- Greenhouse gases then re-emit the energy in all directions
- Long wavelength radiation is thermal energy so heat is trapped by layer of greenhouse gases in atmosphere, result in increased temp in earth's surface

Saturn has other moons. The other moons of Saturn have no atmosphere. Titan is warmer than the other moons of Saturn because its atmosphere contains the greenhouse gas methane.
Explain how this greenhouse gas keeps Titan warmer than the other moons of Saturn. (3)

- Methane allows short wavelength radiation to pass through (from the sun)
- Which is re-emitted from the surface as longer wavelength radiation
- Which is absorbed by methane in the atmosphere

9.2.2 Human activities which contribute to an increase in greenhouse gases in the atmosphere

The amount of carbon dioxide in the atmosphere has increased over the last one hundred years.
Suggest two reasons why this has happened (2)

- Burning of fossil fuels or cars / industry / air travel / power stations
- Natural processes cannot absorb all the extra CO_2
- Deforestation

Name two activities that increase the amount of methane in the atmosphere (2)

- Rice growing
- Farm animals
- Landfill (when rubbish rots → release CH_4)

Give one effect that increasing levels of carbon dioxide in the atmosphere may have on the environment (1)

- Global warming

9.2.3 Global climate change

Explain why global warming is a threat to natural environment. (5) – Geography x Biology

- Melting of ice caps - ↑ sea level - flooding of low lying islands
- Loss of habitats - loss of food sources - disrupt food chain - threat species extinction - ↓ biodiversity
- Coral bleaching - warming of sea water
- ↑ drought - rising temp make dry areas drier - water evaporates quickly

- ↑ flooding - rising temp make wet areas wetter - warm air absorbs more water - heavier rainfall

How burning coal affect amount of CO_2 in Earth's atmosphere? (2)

- Increases CO_2
- Coz carbon in coal reacts with O_2 when being burnt

Suggest 2 reasons why the world's production of coal is predicted to increase (2)

- Growth of population increases demand of coal
- Coal is easy to extract

9.2.4 The carbon footprint and its reduction

Carbon footprint - total amount of carbon dioxide and other greenhouse gases emitted over the full life cycle of a product, service or event

Describe actions to reduce emissions of carbon dioxide and methane

Use renewable energy sources & nuclear power	• No atmospheric pollution
Use biofuels	• Biofuels are made from plant materials • Carbon-neutral - absorb same amount of CO_2 for photosynthesis as released when being burnt
Carbon capture and storage	• Collect CO_2 produced when fuels burnt and store it deep underground for porous rocks to absorb
Increase energy efficiency	• Less energy waste • Eg use LED light bulbs instead of halogen bulbs
More recycling / less landfill waste	• Less waste decomposes so less CH_4 produced
Eat less meat	• Less cattle excretion of CH_4
Gov introduce laws / tax companies	• Tax based on how many greenhouse gases they emit

Give two reasons why actions may be limited (2)

- Expensive cost
- Lack of international agreement
- Increase in population / change in lifestyle

Suggest why burning wood in power stations is 'carbon-neutral' (2)

- CO_2 produced from burning wood
- Plants absorb CO_2 for photosynthesis

9.3 Common atmospheric pollutants and their sources

9.3.1 Atmospheric pollutants from fuels

9.3.2 Properties and effects of atmospheric pollutants

Pollutant	How it's produced	Effects	Solution
Carbon dioxide CO_2 & water vapour $H_2O_{(g)}$	Complete combustion of hydrocarbon fuels Eg $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	Greenhouse gases – enhance greenhouse effect → cause global warming → climate change	-
Carbon monoxide CO	Incomplete combustion of hydrocarbon fuels due to lack of O_2 Eg $2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$	A toxic gas Colourless & odourless so not easily detected Binds to haemoglobin in RBC in place of O_2, leads to health problems	Ensure good supply of O_2 when burning
Sulfur dioxide SO_2	Sulfur impurities with O_2 during combustion to produce sulfur dioxide $S + O_2 \rightarrow SO_2$	Respiratory problems Acid rain – erosion/kills fish	Remove SO_2 from waste gas Remove S from fuels before burning in fuels
Nitrogen oxides NO / NO_2 / N_2O	High temp of internal combustion engines of cars causes $N_2 + O_2 \rightarrow 2NO$	Respiratory problems Acid rain – erosion/kills fish	Catalytic converter in cars
Particulates / soot	If diesel doesn't burn completely, then tiny solid particles of C and unburnt hydrocarbons are produced to form particulates $2C_{14}H_{20} + 15O_2 \rightarrow 28C + 30H_2O$	Global dimming (Particulates in upper atm reflect sunlight back into space → less reaches Earth) Respiratory problems – lung cancer	Ensure good supply of O_2 when burning

Describe how CO_2 is released into the atmosphere from carbonate rocks by geological activity (1)

- Rock is heated then decomposed

Hydrocarbons and calcium carbonate contain locked up carbon dioxide. What is locked up carbon dioxide? (2)

- CO_2 from air formed rocks / fossil fuels

Limestone

Limestone contains calcium carbonate. Name the type of reaction that takes place when calcium carbonate is heated strongly and the products formed. (3)

- Thermal decomposition
- To produce CaO and CO_2

$2CaCO_3 + 2SO_2 + O_2 \rightarrow 2CaSO_4 + 2CO_2$

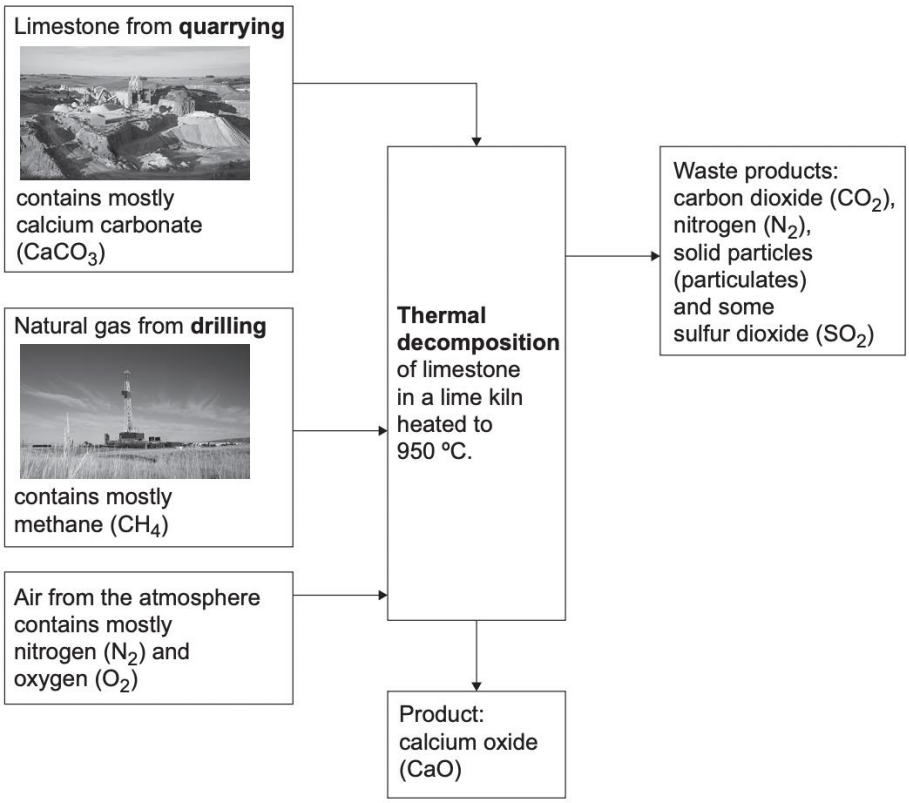
How does limestone used in power station release CO_2 and SO_2? (1)

- CO_2 - thermal decomposition
- SO_2 reacts with $CaCO_3$

In this question you will be assessed on using good English, organizing information clearly and using specialist terms where appropriate.

Limestone is heated in a lime kiln to produce calcium oxide. Figure 4 shows the reactants used and the products made in a lime kiln.

Figure 4



Use information from Figure 4 to explain the potential environmental impacts of quarrying, drilling and the thermal decomposition of limestone used in the production of calcium oxide. (6)

Examples of chemistry points made in the response could include:

Processes	Types of pollution and problematic effects
• Quarrying • Drilling • Thermal decomposition • Combustion of fossil fuel • Use of explosives	• Visual pollution • Noise pollution • Dust pollution • Destruction of land • Air / atmospheric pollution (CH_4, CO_2, SO_2, NO_x, particulates) • Water (rivers / lakes / seas) pollution • Earth tremors

Environmental impacts:

- Destruction of areas of natural beauty
- Disturbance of people and animals
- Breathing problems or asthmatic attacks
- Destruction of habitats or biodiversity or kills wildlife and plants
- CH_4 and CO_2 - greenhouse gases → global warming → consequences
- Particulates - global dimming → consequences including breathing problems
- SO_2 and NO_x - acidic gas / rain → consequences including breathing problems
- Damage to buildings / infrastructure